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Shoudong Feng
University of Central Arkansas, sfeng@uca.edu

Umadevi Garimella
University of Central Arkansas

Carolyn Pinchback
University of Central Arkansas

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Shoudong Feng
University of Central Arkansas

Umadevi Garimella
University of Central Arkansas

Carolyn Pinchback
University of Central Arkansas

ABSTRACT

In this paper, the results of a study of teachers' dispositions and classroom practices regarding literacy integration into STEM courses are presented. The Connection Core Concepts (CCI) program, developed through Mathematics and Science Partnership (MSP) grant funds, was designed to support the integration of content across subject areas. Literacy is one of the emphases in Integrated STEM to enhance teacher content knowledge and increase student success. Research data were gathered from 30 teacher participants from Grades 5–8 through surveys, observations and interviews. The results indicated that there were positive changes in teacher perceptions as well as classroom practices in regard to integrating literacy into STEM.

Keyword: STEM; literacy; Integration; Dispositions; Practices

Background

The authors of this paper were involved in a three-year Math and Science Partnership (MSP) grant program to provide teacher professional development that was focused on improving STEM teachers' content knowledge and providing tools for them to implement the new state science standards. Each year a specific science content was addressed: Physical Science in year 1, Earth and Space Science in year 2, and Life Science in year 3. A team of university faculty members representing various disciplines collaborated closely to provide training in current science content knowledge and best practices in Integrated STEM education. One of the key areas of the training was literacy integration. A three-year training plan that included the integration of reading comprehension strategies, vocabulary/concept development strategies and writing strategies into life science, physical science, earth science, math, and some other STEM classes was designed and implemented. A statistical analysis of data collected through pre- and post-tests, a minimum of two classroom observations, and interviews of a random sample of participants was conducted to evaluate the effectiveness of the program.

The project was housed in the Institute for STEM Professional Development and Education Research (STEM Institute) at a public university in the southwest United States. In collaboration with a neighboring Educational Cooperative, the STEM Institute created an ongoing partnership between high-need school districts and STEM faculty from the College of Education and the College of Natural Sciences and Mathematics. Science initiatives were developed to enhance learning outcomes that support the implementation of new state standards which are based on Next Generation Science Standards (NGSS). The initiatives included multimodal instructional models that support multiple forms of assessment and provided a long-term and sustainable high-quality professional development opportunity for a minimum of 100 contact hours during each year of the project. This included a two-week summer institute, four Saturday sessions during the academic year, and two classroom observations.

The project focused on the improvement of science instruction in grades 5-7 by integrating mathematics, literacy, and technology to enhance teacher content knowledge and teaching skills that prepare students for success. To better understand the participating teachers' dispositions and classroom practice and the impact of training, questionnaires were developed and administered each year. In this paper, the authors intend to report the findings of the pre- and post-training surveys to assess the impact of the training. The results from this study were used to evaluate and adjust the training. The authors hoped that the data may also provide literature in the area of Integrated STEM education and specifically literacy integration into STEM subjects.

Literature Review

According to Brown (2012), and Mizell & Brown (2016), based on their analysis of the articles published in eight major STEM-focused journals from 2007 to 2015, Integrated STEM was the most-researched theme in STEM research. This integration was mainly an effort to address the separation of the STEM disciplinary areas, as Moore and Smith (2014) state, "[I]n general, integrated STEM education is an effort to combine the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections among these disciplines and real-world problems. More specifically, STEM integration refers to students participating in engineering design as a means to develop relevant technologies that require meaningful learning through integration and application of mathematics and/or science." (p. 5) However, some researchers and educators call for the integration of art, English language arts, social studies, and other subject areas to address the disconnected traditional STEM education model (Gess, 2017; Sanders, 2009). Given the importance of literacy in learning and communicating content knowledge, STEM researchers and educators should consider including this important piece in the puzzle.

Historically, one area of research in disciplinary literacy was teachers' beliefs about integrating literacy into their respective content areas and their classroom practices. The traditional view on the issue was that content area teachers were only responsible for teaching the content, not reading or writing (Ratekin et al., 1985; Siebert & Jo Draper, 2008; Stewart & O'Brien, 1989). The content area teachers expected their students to be able to read and write when they came to their classrooms. Yet, current educational standards such as Common Core State Standards (CCSS) and

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Next Generation Science Standards (NGSS) clearly require the teaching of literacy in content areas as evidenced in the following standards: CCSS Literacy Standards for History and Social Studies, Literacy Standards for Science and Technical Subjects, and the reading and writing standards in NGSS. Hence, content area and STEM teachers are mandated to change their dispositions and classroom practice to meet these teaching standards. In this new era of standards-driven education, do STEM teachers embrace this change? Have they adopted new teaching practices to include reading and writing in content area learning? Will this training lead to any change in their dispositions and classroom practice? The survey research would help the authors better understand the above questions.

The limited research on this topic seems to have yielded inconsistent findings. For example, in a year-long literacy professional development project, Cantrell et al. (2009) conducted a pre- and post-survey on middle and high school content area teachers' beliefs about literacy integration and found that most content area teachers' dispositions turned more positive through the training. They reported that most teachers believed that literacy was integral to their content areas, and they viewed themselves as both literacy teachers and content teachers. Although the teachers admitted that they encountered a number of barriers during the initial phases of implementing literacy strategies, they claimed that professional development with coaching and collaboration changed their efficacy and classroom practice. Huysman (2012) confirmed this finding on teachers' attitude change through professional development for high school content area teachers.

Edwards et al. (2015) compared the dispositions and classroom practices pertaining to literacy instruction in STEM classes between those who received literacy training and those who did not. They found no differences between the two groups. In terms of STEM teachers' competence to integrate literacy, research shows consistent results in that the teachers may be well trained in their respective content areas, but lack the knowledge and skills to incorporate literacy into their content area instructions (D'Arcangelo, 2002; Vacca, 2002). Fisher and Frey (2008) concluded that content area teachers know relatively little about vocabulary instruction, one of the key instructional areas in content learning. Research suggests that professional development that is focused on instructional strategies will produce a positive impact on student achievement. For example, Falk-Ross & Evans (2014) found that a teacher professional development training on integrating vocabulary strategies into content areas improved student reading comprehension, vocabulary use, and overall student achievement.

The authors of this study believe that in order to meet the new educational standards, it is imperative that STEM teachers possess a positive disposition regarding literacy integration and know how to implement literacy strategies in content area instruction. This study aimed to investigate the impact of literacy integration training on teachers' beliefs and practices regarding literacy integration into their STEM classes.

Method

Participants

The participants involved in the three-year study were Grades 5-8 public school teachers in a southwestern state in the US. A cohort of 30 teachers were recruited in the first year of the project.

To ensure the effectiveness of the professional development training, the same cohort of teachers were required to participate in all three years of the project. If any participants discontinued due to professional or health reasons, they were replaced by new recruits with a similar background. Most of the teachers were from small rural school districts and were teaching multiple STEM content areas such as life science, physical science, earth science, and mathematics. Some of them were self-contained special education teachers. Teaching experience ranged from one to twenty years, with an average of 8.4 years. There were three male and 27 female teachers. Of all the teachers in the study, 89% were Caucasian and 11% were African American.

Procedures

In order to measure the impact of professional development training on participating teachers' beliefs and classroom practices, the research team constructed a 20-item Likert scale questionnaire and conducted two classroom observations. Another set of questions were included to collect the demographic information. The questionnaire was reviewed by two experts in educational research and tested in a small group of undergraduate students. The items were then revised based on the feedback from the experts and the analysis of the responses from the pilot group to ensure validity. The twenty questions were categorized into three groups: one set to probe the participants' perceptions (two about literacy integration, two about their role and responsibility, and two about their students' ability), one set to measure their knowledge and skills in regard to literacy integration (nine questions), and one set to examine their actual classroom practice (five questions). More specifically, seven questions in the questionnaire were about reading, seven about writing, three about vocabulary instruction, two about the availability of trade books for content area supplement, and one about grouping strategies. Questions range from their beliefs about the importance of involving students in reading and writing in STEM classes, to their perceptions of their role and responsibilities in utilizing reading and writing strategies to teach STEM content, to their beliefs about their classroom practices regarding literacy integration (reading, writing, and vocabulary).

The questionnaire was administered at the beginning of the first-year training as a pre-assessment and at the end of the year as a post-assessment. In the pre-assessment, out of the thirty participants, 22 returned valid responses, which were included in the analysis. In the post-assessment, 25 valid responses were returned and included in the analysis. Some demographic information such as the grade level the participants teach, the content area(s) they teach, and their years of teaching experience was also collected and examined.

The Reformed Teaching Observation Tool (RTOP, Pilburn & Sawada, 2000) was used for classroom observations. To establish baseline teaching practices regarding pedagogy and content, STEM faculty visited the classrooms of the participating teachers during the fall semester of the first year of the program and in the spring of the last year. Developed as an observational tool to measure reformed teaching, or teaching that shifts from the traditional teacher-centered classroom to a learner-centered classroom that is collaborative, integrated, and activity-based, the RTOP is comprised of 25 items across three subsets: Lesson Design and Implementation (5), Content (10), and Classroom Culture (10). Sample items from the three subscales are, "In this lesson, student

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exploration preceded formal presentation," "The lesson promoted strongly coherent conceptual understanding," and "There was a climate of respect for what others had to say." Observers rate teachers on each item using a five-point scale of 0 to 4 with anchors of Never Occurred and Very Descriptive resulting in possible RTOP scores ranging from 0 to 100. Previous studies of score reliabilities reported inter-rater reliability estimates ranging from .90 to .95 for the total score and .67 - .95 for subset scores (Piburn & Sawada, 2000). Piburn and Sawada (2000) provided a discussion of face, construct, and predictive validity and concluded that, "Analysis of the RTOP suggests that it is largely a uni-factorial instrument that taps a single construct of inquiry… the instrument seems amply able to measure what it purports to measure regarding reformed teaching" (p.27).

The research questions the current study intended to answer include the following:

1. Will the training impact the participants' beliefs about the importance of integrating literacy into STEM classes and their responsibilities to integrate literacy?
2. Will the training impact the participants' beliefs about their knowledge and skills in integrating literacy into STEM classes?
3. Will the training impact the participants' classroom practice?

Results

As discussed previously, two questions were about the participants' perception of integrating literacy into STEM classes. They were asked if integrating reading and writing is important in STEM instruction. In the pre-assessment, four participants chose "Strongly Disagree" on both reading and writing to indicate they do not believe that it is important to integrate literacy into STEM classes. No one chose "Disagree" on either reading or writing. Four chose "Agree" on reading and three chose "Agree" on writing, and 14 chose "Strongly Agree" on reading and 15 chose "Strongly Agree" on writing. On the post-assessment, one participant chose "Strongly Disagree" on both reading and writing. No one chose "Disagree" on either reading or writing. Three chose "Agree" on reading and five chose "Agree" on writing, 21 chose "Strongly Agree" on reading and 19 chose "Strongly Agree" on writing. To summarize, on the importance of integrating reading, 18 chose "Agree" or "Strongly Agree" before the training and 24 chose "Agree" or "Strongly Agree" after the training. On the importance of integrating writing, 18 chose "Agree" or "Strongly Agree" before the training and 24 chose "Agree" or "Strongly Agree" after the training.

As the figure shows, after training, there was a 14% increase (82 to 96) in the number of participants who believe it is important ("Agree" or "Strongly Agree") to integrate reading and writing into STEM classes. It should also be noted that 18% of the participants chose "Strongly Disagree" that reading or writing is important in STEM learning.

On the two questions that asked if they believe that they have the responsibility to integrate reading and writing into STEM classes, in the pre-assessment, three participants chose "Strongly Disagree" on reading and two chose "Strongly Disagree" on writing. One participant chose "Neutral" on both reading and writing, five chose "Agree" on both reading and writing, and thirteen chose "Strongly Agree" on both reading and writing. In the post-assessment, no one chose "Strongly Disagree" or "Disagree" on either reading or writing. One participant chose "Neutral" on both reading and writing, five chose "Agree" on both reading and writing, and 19 chose "Strongly Agree" on both reading and writing. In summary, before the training, 18 participants chose "Agree" or "Strongly Agree" that it is their responsibility to integrate reading and writing into STEM areas. After the training, 24 participants chose "Agree" or "Strongly Agree" that it is their responsibility to integrate reading and writing into STEM classes.

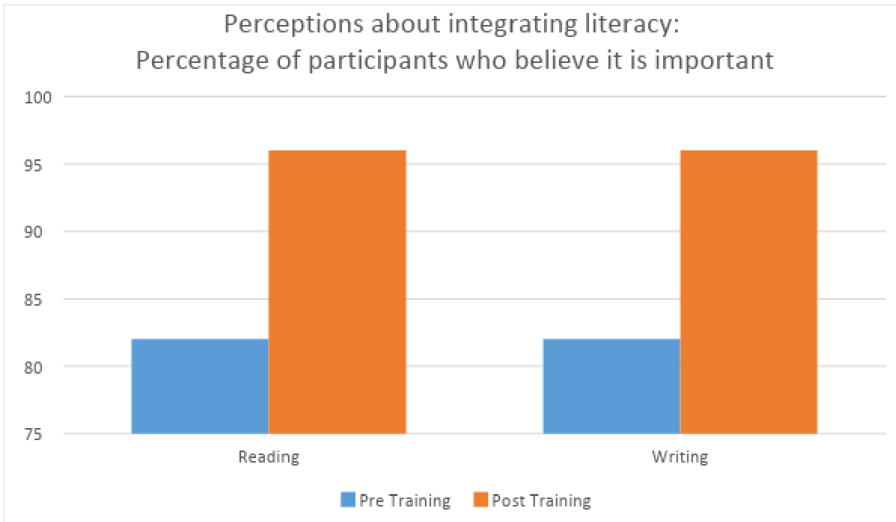

Figure 1. Findings on perceptions about the importance of integrating reading and writing

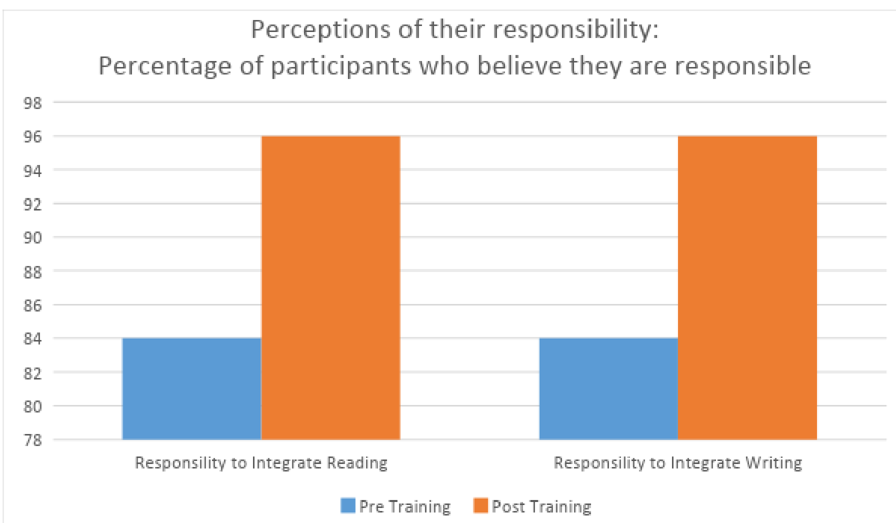

Figure 2. Findings on participants' beliefs about their responsibility to integrate literacy

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According to the above data, in terms of the participants' perceptions of their responsibility in integrating literacy, there was a 12% increase on both reading and writing. On these two questions, no participants chose "Strongly Disagree" or "Disagree."

On the last set of questions that examine the perception of change in classroom practice, it is a slightly different scenario. In the area of reading, there was a 24% increase in the number of teachers who believed that they regularly involve students in reading STEM materials after the training. In writing, 16% more teachers believed they regularly involve students in writing in STEM classes. After the training, 25% more teachers regularly taught vocabulary in STEM classes. Data indicates that the training changed many teachers' classroom practice and 25% more teachers incorporated reading, writing, and vocabulary in STEM subjects.

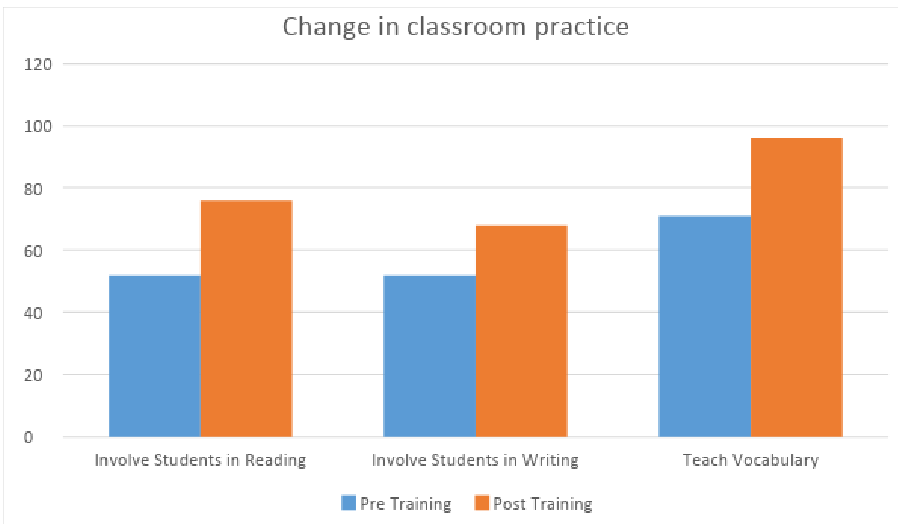

Figure 3. Findings on beliefs about teaching practice

To measure the teacher implementation throughout the 3-year grant period, the first RTOP observation scores from year 1 were compared (as a baseline measure) to the last observation scores from year 3, providing a measure of change over time. An Independent Samples T Test was conducted on each of the three subscales of Lesson Design, Content Total, and Classroom Culture. Results on the Lesson Design Total subscale scores showed a statistically significant effect when comparing the two time periods (year 1 M=18.32, SD 5.91; year 3 M=15.04, SD = 2.46; t(32.63)= 2.54, p= .02). This indicates that over the three years of the professional development, teachers implemented significantly less of these elements into their practice. Results on the Content Total subscale scores show a statistically significant effect when comparing the two time periods (year 1 M=21.48, SD 4.25; year 3 M=34.22, SD = 3.44; t(46)= -11.35, p= .000). The data shows that over the three years of the professional development, teachers implemented significantly more of the elements into their classroom practice. Results on the Classroom Culture Total subscale scores showed a statistically significant effect when comparing the two time periods (year 1 M=24.32, SD 6.08; year 3 M=33.87, SD = 3.01; t(35.69)= -6.98, p= .000). This indicates that over the three years of the professional development, teachers implemented significantly more of the elements into their classroom practice.

Discussion and Implications

Integrating literacy into STEM courses is crucial for students to succeed in those areas because students have to read and write in all content areas to learn and communicate. STEM teachers' beliefs about literacy integration have profound impact on whether the teachers incorporate vocabulary, reading, and writing activities in the content areas. It is important that teachers have positive dispositions regarding literacy integration and the knowledge and skills to do so.

This research intended to determine the impact of training on teacher perceptions and classroom practice in integrating literacy into STEM classes. Results suggest that the training had a positive impact on STEM teachers' dispositions as well as their classroom practice. There was a 14 % increase in the number of participants who believed it was important to integrate reading and writing into STEM subjects and 12% increase in the perception of personal responsibility to do so. A higher percentage of participants changed classroom practices as a result of the training, with about 25% indicating that they incorporated the reading and vocabulary strategies and 16% incorporated the writing strategies they learned in the training. It should be noted that 18% of the participants "Strongly Disagree" that reading or writing is important in STEM learning.

Classroom observations of the year three showed a significant increase in the quality of literacy integration in science classes as compared to year 1. Before the training, science teachers used definitions of the vocabulary words, note-taking, bell ringers, and lab notebooks while the mathematics teachers used open response questions, explaining the steps used in solving the problems, and rewriting the word problem in their own words. However, the observation after the training showed that teachers used several other strategies in their classes. For example, a science teacher had students make a list of names of muscles and bones and classify them based on their understanding of common characteristics. Students of another teacher started a lab by looking at the weather readings in the newspaper, did a close reading of an article, and identified the author's purpose and the central idea. Strategies such as compare and contrast and students researching a disease of their choice of the circulatory system using primary sources and creating a Power-Point slide to share with their class were also observed.

Participants who had been in the professional development program for all three years were asked to interview in year 3 to ascertain overall impact of the professional development. Four people volunteered to speak to the evaluator. All participants in the professional development were administered the exit survey. There was a total of 29 survey responses. The exit survey showed that 79.5% of respondents indicated that they were either satisfied or extremely satisfied with the professional development training. The qualitative portion of the survey and the interviews triangulated with two respondents reporting that they thought some of the content was outside their area of expertise and some of the content was too complex to assimilate in the time given for the lesson. Three respondents did not find the extra articles given to them to read valuable.

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The positive impact of the professional development training can be attributed to the teamwork of university faculty to the intentional pairing of literacy strategies to the science topic in each module. By incorporating a balanced literacy approach into each science concept that was addressed, participating teachers were engaged in an authentic science experiment and content literacy strategies to make meaning of the science concepts rather than take meaning from established resources. In other words, the integration of science and literacy instruction helped teachers contextualize their scientific observations.

Although there were some inherent limitations associated with survey research, the training led to a positive impact on teacher dispositions and classroom practices.

According to the 2010 National Survey on STEM Education, one of the top challenges in STEM Education is insufficient teacher professional development (National Survey on STEM Education, 2010). In order for STEM teachers to change their attitudes and classroom practice regarding literacy integration, more effective professional development should be provided, as found in this three-year investigation.

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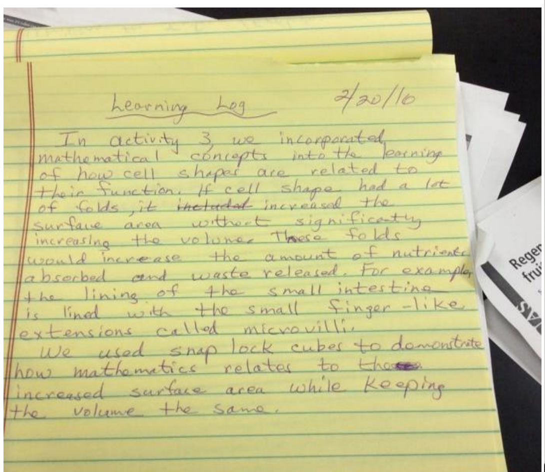
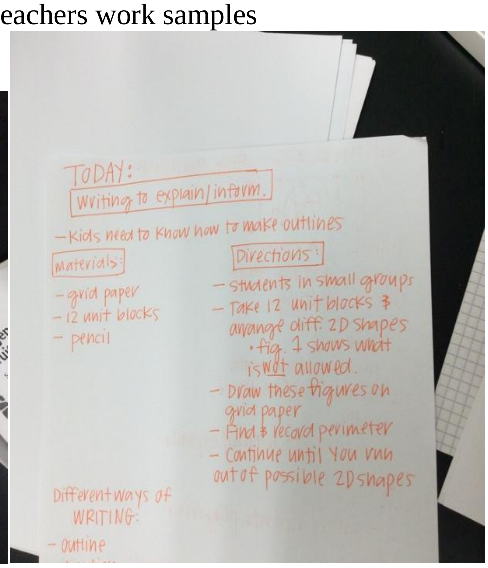
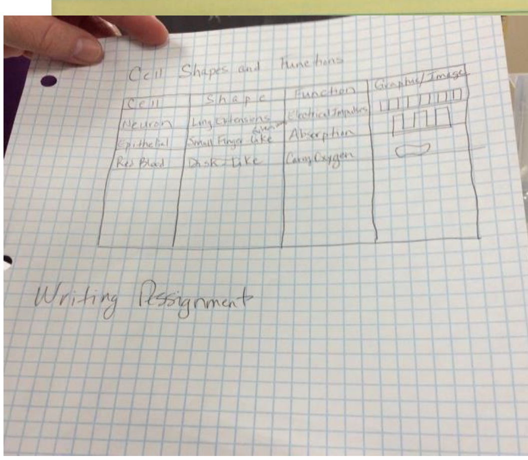
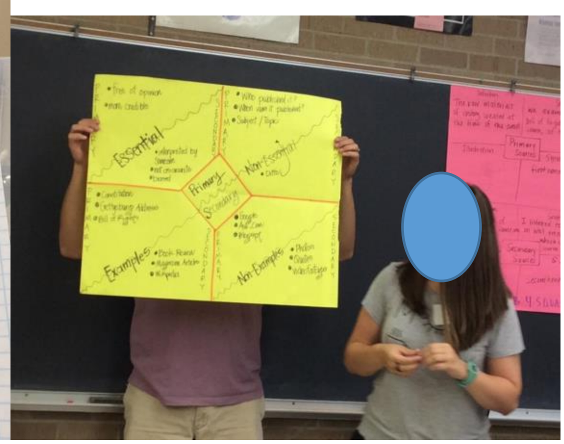
Appendix

Participating teachers work samples









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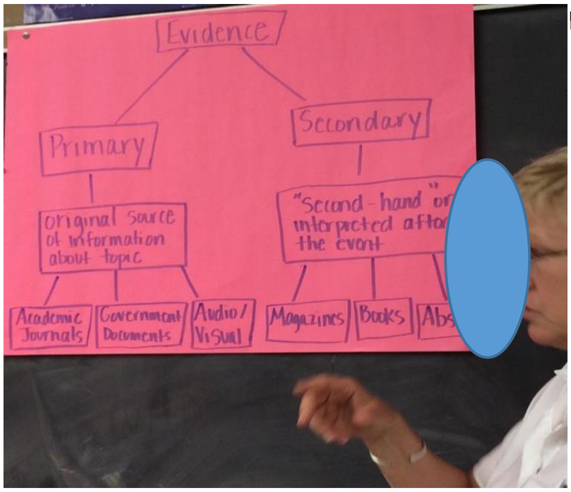

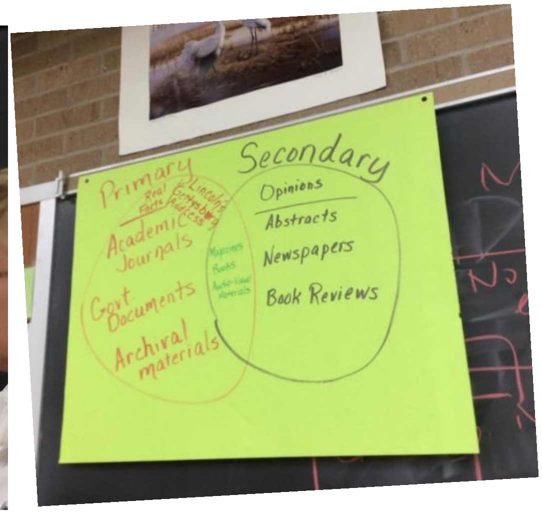

Authors

Shoudong Feng
Associate Professor
University of Central Arkansas, Department of Elementary, Literacy, and Special Education
Email: sfeng@uca.edu

Umadevi Garimella
Director
University of Central Arkansas, STEM Institute
Email: ugarimel@uca.edu

Carolyn Pinchback
Professor
University of Central Arkansas, Department of Mathematics
Email: carolinp@uca.edu